

Internet Protocol Telemedicine and Pediatric Cardiology Education (N01-LM-9-3541)

Center for Health Sciences Communication
East Carolina University
Brody School of Medicine

Overview

- Introduction
- Major Technology Evaluations
- Findings and Recommendations
- The Future of IP Telemedicine

Project Team

- Susan Gustke, M.D. (PI)
- David Balch, M.A. (Co-I)
- Vivian West, Ph.D.
- William Chimiak, Ph.D.
- Ron Rouse
- Alan Branigan, M.S.
- Scott Simmons, M.S.
- Tony Cooke
- Chad Waters
- Mark Harrington
- Charles Ponton
- Diane Darrow
- Carolyn Bunting
- Joseph Babb, M.D.
- David Hannon, M.D.
- Paul Cunningham, M.D.
- Daniel Moore, M.D.
- James Wells, M.D.
- Phil Bryant, M.D.
- Robert Hoyer, M.D.
- Gloria Jones
- Adrian Blannarovich, M.S.
- Tim Murphy
- Ted Kummer
- Gwen Godley
- Phil Lunsford, Ph.D.

ECU Telemedicine Overview

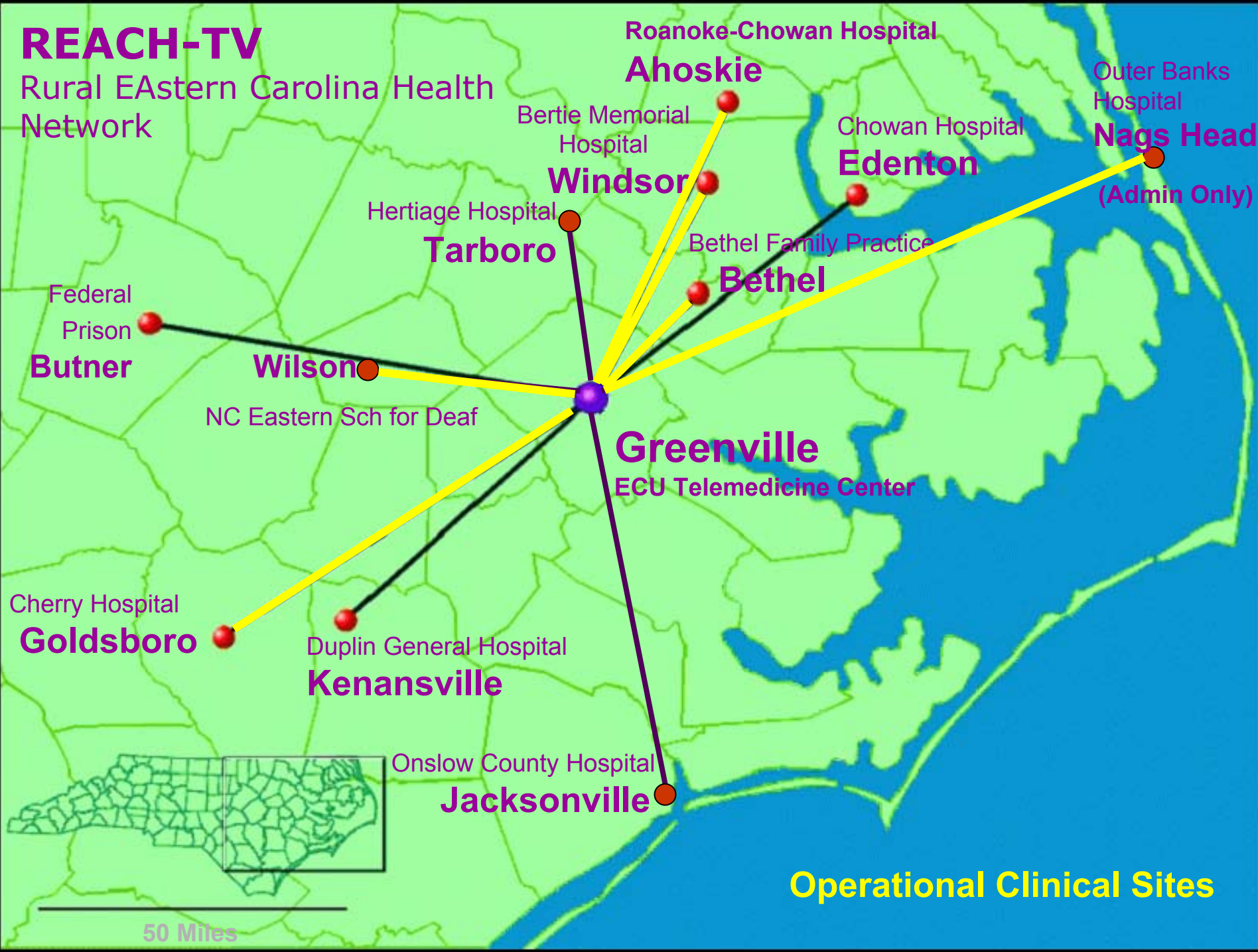


- All circuit-switched N/W prior to NLM contract
 - T-1
 - ISDN
 - POTS
- Active since 1991
- 14,000 mi² service area
- Also distance learning and grand rounds



REACH-TV

Rural EAsTern Carolina Health
Network



Roanoke-Chowan Hospital
Ahoskie

Bertie Memorial
Hospital

Windsor

Hertiage Hospital

Tarboro

Chowan Hospital
Edenton

Outer Banks
Hospital
Nags Head
(Admin Only)

Bethel Family Practice
Bethel

Greenville
ECU Telemedicine Center

Federal
Prison
Butner

Wilson

NC Eastern Sch for Deaf

Cherry Hospital
Goldsboro

Duplin General Hospital
Kenansville

Onslow County Hospital
Jacksonville

Operational Clinical Sites

50 Miles

Impetus Behind this Project

- The Promise:
 - IP networks pervasive (ubiquitous?)
 - Can serve multiple applications, versus dedicated circuits for “traditional” TM
- The Reality:
 - IP networks not designed or optimized for videoconferencing

Contract Overview

Five Primary Objectives

1. IP telemedicine (10 specialties)
2. Store-and-forward cineangiograms
3. Electromyography
4. Pediatric cardiology education
5. Microwebrowsers



Major Technology Evaluations

Technology Foci

- Interactive Teleconsultation
 - IP videoconferencing: Objectives 1 & 3
- Store & Forward Teleconsultation
 - Cineangiograms: Objective 2
- Distributed Multimedia Education
 - Pediatric heart sounds: Objective 4
- Microwebrowsers
 - Vital signs, audiometry: Objective 5



Major Technology Evaluations: *Interactive Teleconsultation*

H.323 basics

- H.323 is the International Telecommunications Union (ITU) standard for network/IP videoconferencing
- A family of standards:
 - H.261, H.263: video codec
 - G.711, G.722, G.728: audio codec
 - T.120: multimedia conferencing

MPEG basics

- MPEG-1:
 - 352 x 240 pixels
 - 30 frames/second
 - CD-quality audio
- MPEG-2:
 - 720 x 480 pixels
 - 30 frames/second
 - Surround Sound audio

CODEC & Network Performance

- First test in lab, then in clinical setting
- Lab testing:
 - SMPTE time code – dropped video frames
 - Video test equipment – objective video quality
 - Clinical opinion of diagnostic quality using “gold standard” sources
- Clinical testing:
 - EMG’s: Tarboro & Edenton via T-1, Windsor via microwave Ethernet
 - Pediatric Echo’s: Wake Forest via Internet 2
 - Specialty Consults: Windsor & Ahoskie via microwave Ethernet

Advertised vs. Actual FPS

CLI @ 768 (H.320) = 29 fps

		14.5MIN IN
ON TAPE		CLI
FRAMES		768
1		1
2		2
3		3
4		4
5		5
6		6
7		7
8		8
9		9
10		9
11		10
12		12
13		13

VCON @ 768 (H.323) = 14 fps

ON TAPE		8.5MIN IN	
		VCON @	
		768	
FRAMES			
1		3	
2		5	
3		5	
4		5	
5		8	
6		8	
7		10	
8		10	
9		11	
10		13	
11		13	
12		16	
13		16	
14		17	
15		17	
16		19	
17		19	

Advertised vs. Actual FPS (cont'd)

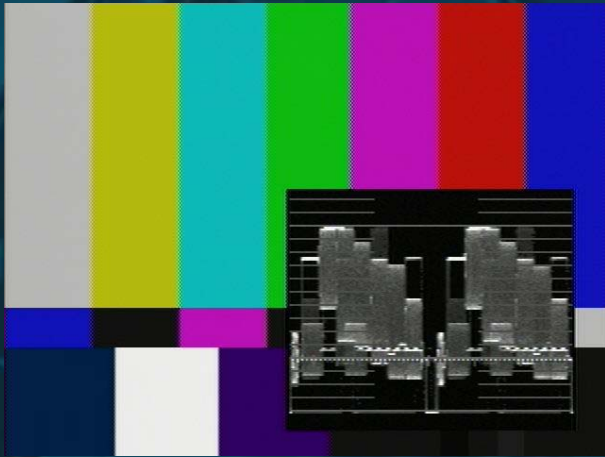
Proshare @ 400 (H.323) = 15 fps

Polycom @ 768 (H.323) = 26 fps

OnTape		PROSHAR
FRAMES		@ 400
1		1
2		1
3		3
4		3
5		5
6		5
7		7
8		7
9		7
10		9
11		11
12		11
13		11
14		13
15		15
16		15
17		17

ON TAPE		POLYCOM
FRAMES		VIEWSTATION
		768
1		1
2		3
3		4
4		5
5		6
6		7
7		8
8		8
9		9
10		10
11		12
12		13
13		13
14		15
15		15
16		16
17		18

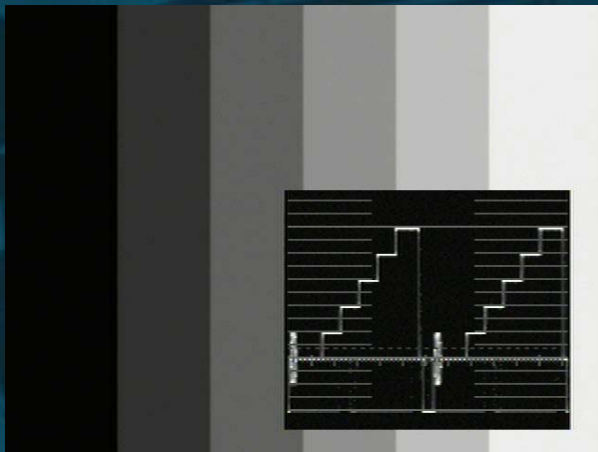
Video Testing



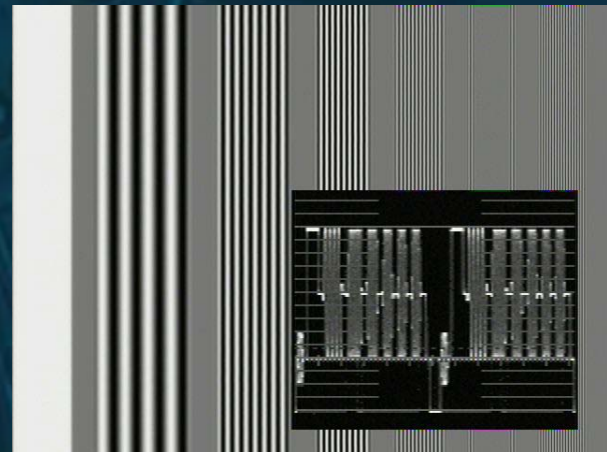
SMPTE Color Bars – Waveform
(Saturation)



SMPTE Color Bars – Vectorscope
(Hue)



Luminance 5 Step
(Linearity)



Multiburst 100
(Detail)

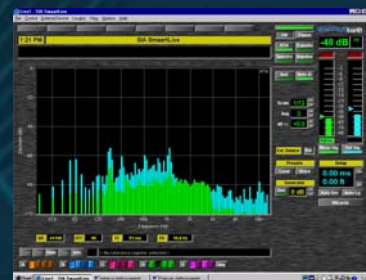
Audio Testing

White Noise



Polycom

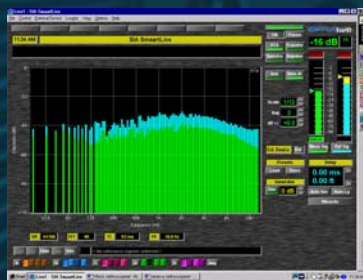
Stethoscope



Polycom



Vbrick



Minerva



Vbrick



Minerva

Physician Assessment of Dx Quality

- Gold standard DV tapes developed in 10 specialties: Adult Cardiology, Allergy, Dermatology, Endocrinology, Obstetrics, Pediatric cardiology, Psychiatry, Pulmonology, Rehabilitation Medicine, Trauma
- Tapes played through codecs with different network (bandwidth) settings
- Three physicians/specialty assessed point at which video/audio was unusable for Dx
- Results used to select codecs for regional network

Internet 2 Pediatric Cardiology

- Internet 2 connection (NCREN) between ECU and Wake Forest
- VBrick 3200 (MPEG 1) codecs
- 20 patients (10 in each direction)
- Tested agreement between in-person and tele-diagnosis
- Sessions comprised patient interview, stethoscopy, and echocardiography
- No clinically significant disagreement measured

Tele-EMG (Objective 3)

- Need to transmit waveform, audio, video of patient (needle placement)
- Progression of solutions tried
 - Scan conversion of VGA
 - 2-camera approach
 - Direct IP telemetry (device modification)
 - Remote control software
 - Tandberg DuoVideo
 - Polycom Visual Concert

Polycom Visual Concert

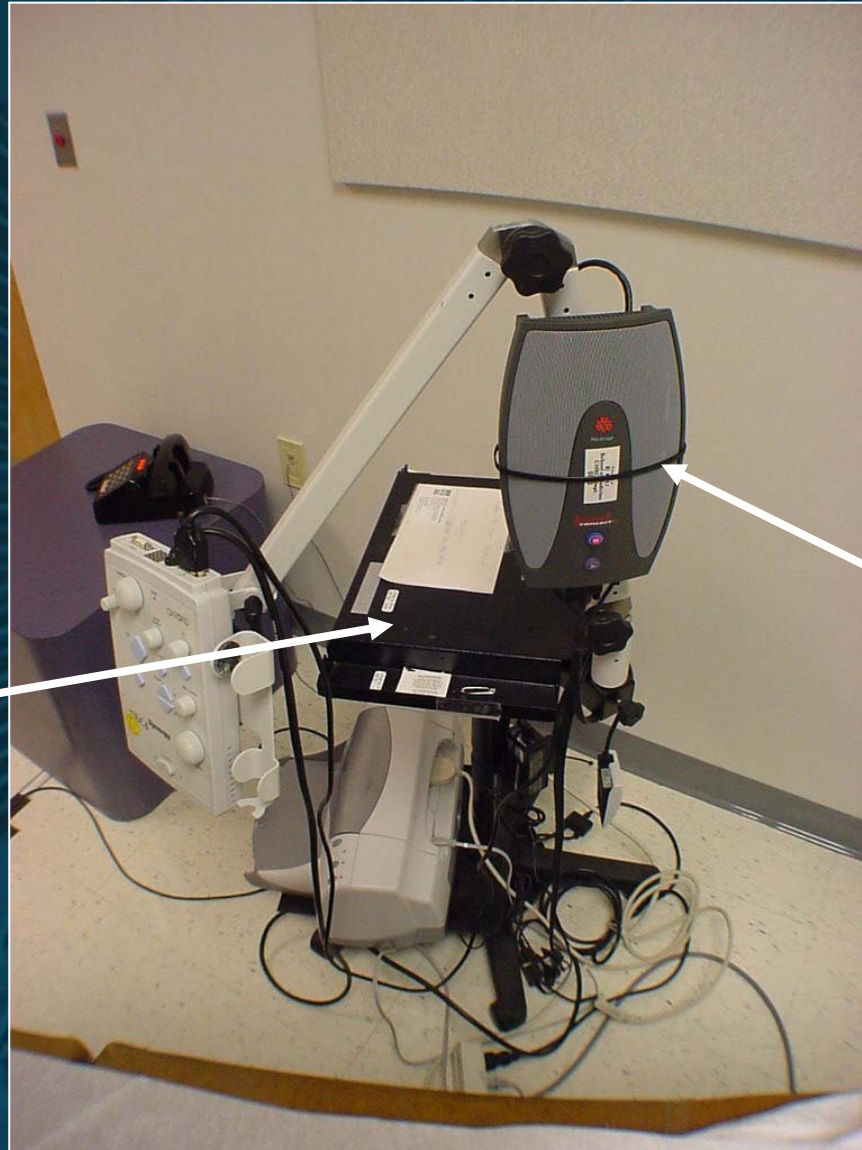


Play & Stop buttons



VGA input

Chowan Hospital Setup (Edenton)



EMG
notebook PC
goes here

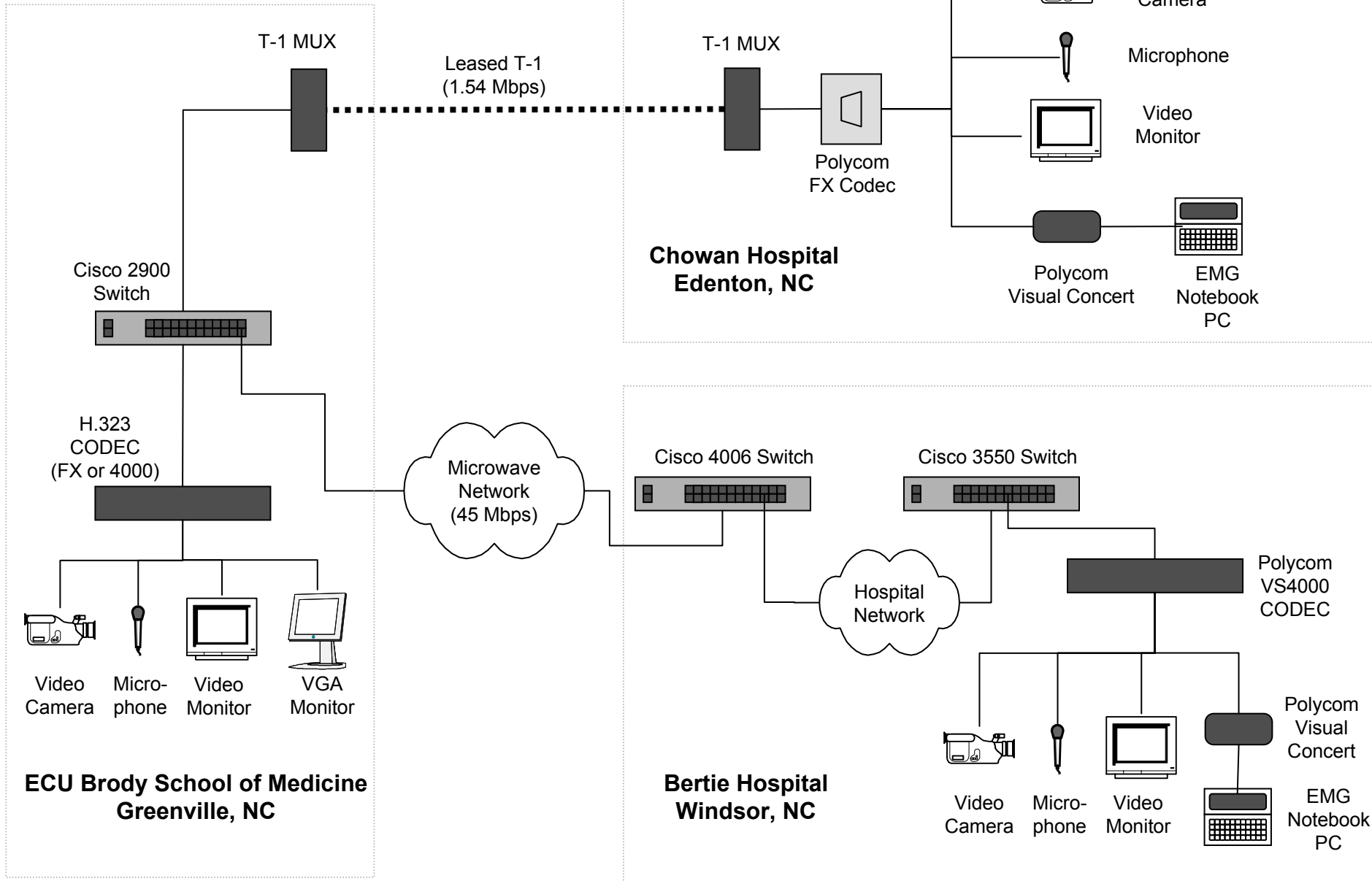
Visual
Concert

Bertie Hospital Setup (Windsor)

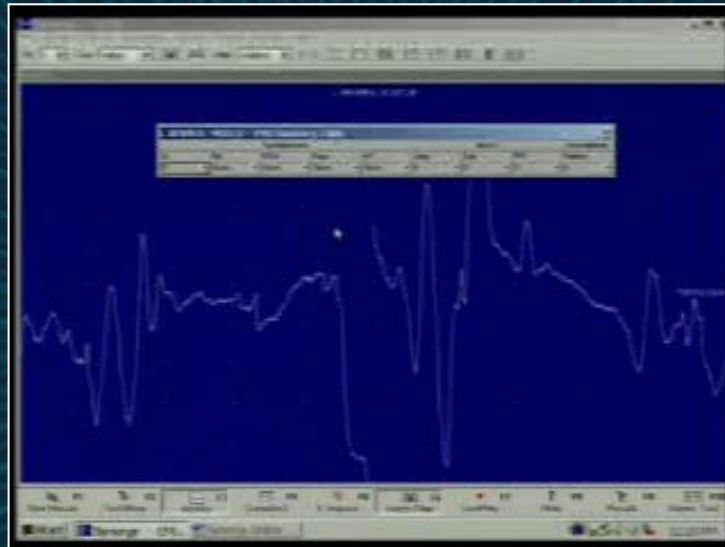


Visual
Concert

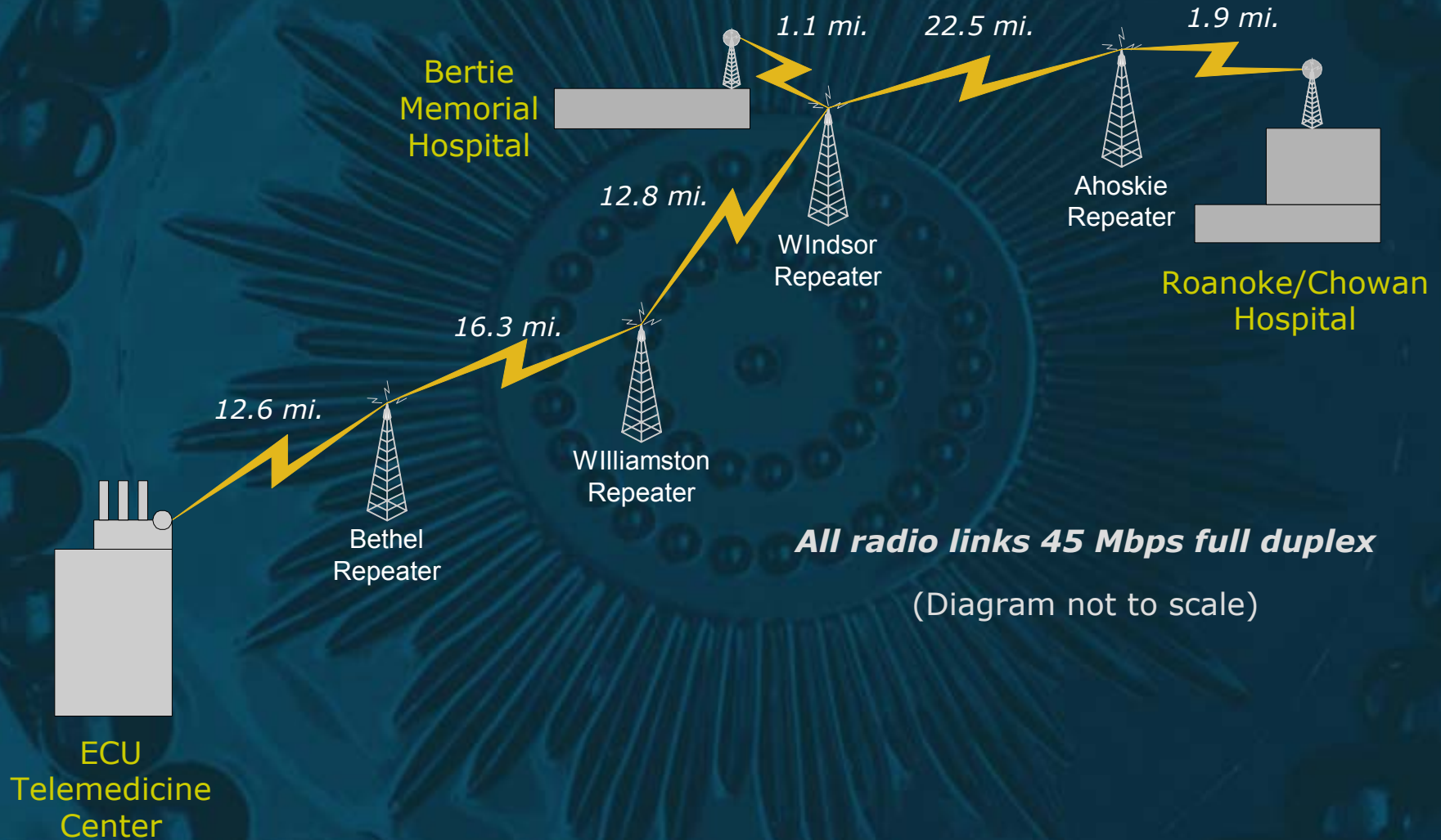
Final EMG Setup



Sample EMG



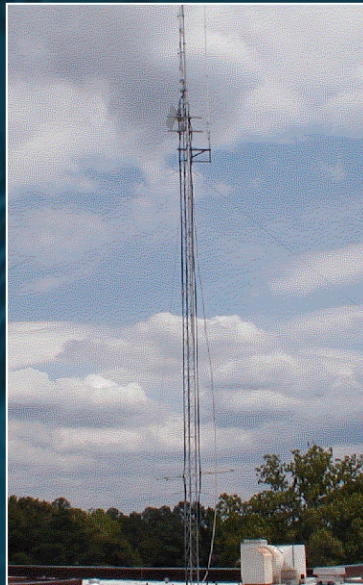
Regional Wireless Network Overview



Network Design

- Selected a microwave Ethernet solution (Proxim Tsunami Wireless Ethernet Bridges)
- Commercial repeater towers
- VLAN in hospitals to connect microwave N/W to codecs
- L2 switches at repeater towers
- L3 switches at hospitals
- IP-enabled A/V switching
- Backup power

Setup Gallery



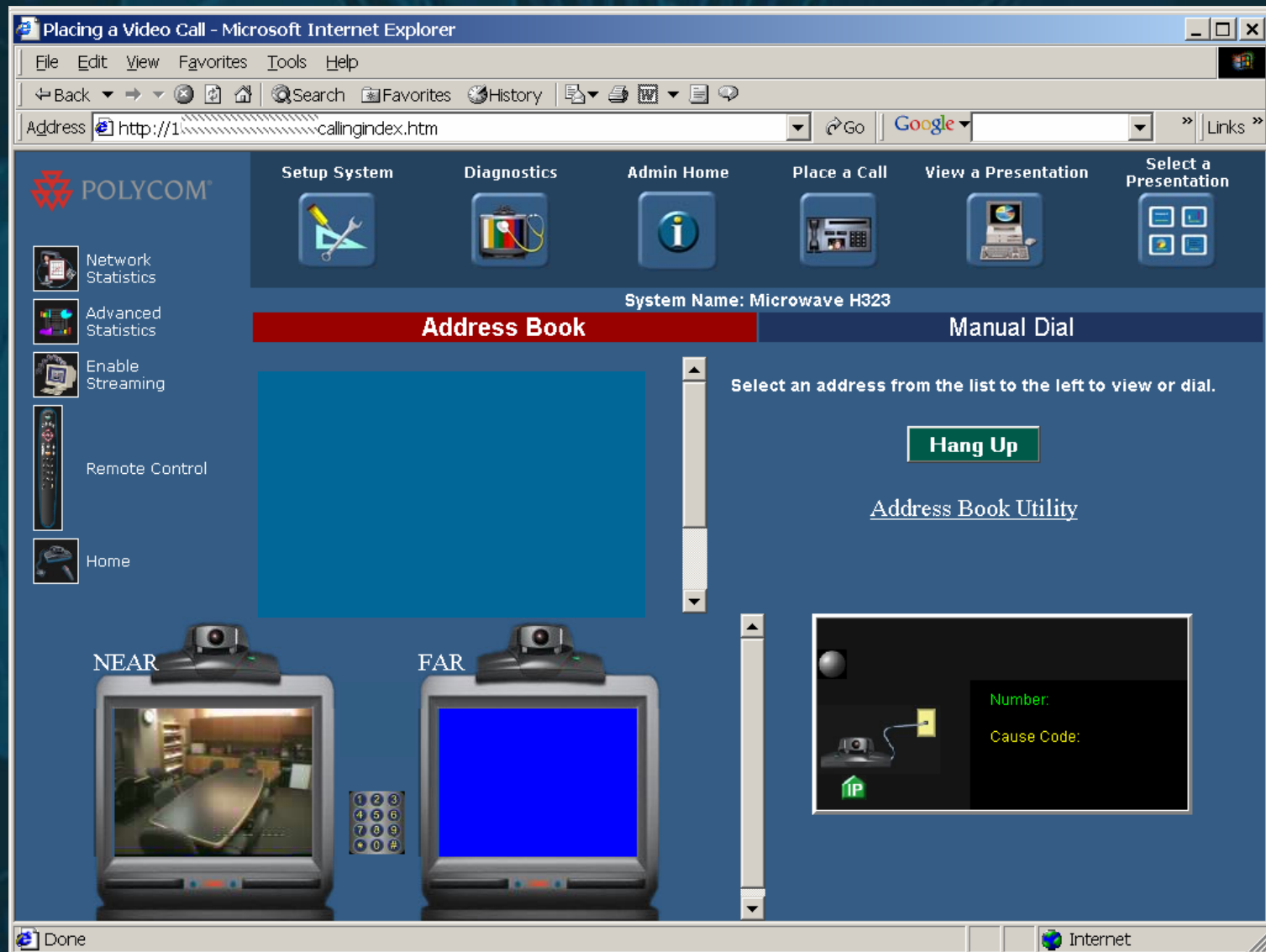
Setup Gallery



N/W Performance Measurement

- Ping tests
- Radio performance
 - From SNMP MIB's
- Video tests
 - Packet loss from codec mgt. interfaces
 - Linux shell and Python scripts
- Port monitoring on N/W devices
- Fluke Optiview Network Analyzer

Web Interface





Major Technology Evaluations: *Store & Forward Teleconsultation*

Original SOP (Pre-NLM)

- Cardiac cath. lab at Nash performs cine study
- Study transferred to another machine to burn CD
- CD delivered to PCMH cardiology via courier or FedEx (6 hrs. – 2+ days)
- Study reviewed by cardiologist
- Patient scheduled for procedure if necessary (1-2 days)

New SOP via IP network

- Cardiac cath. lab at Nash performs cine study
- 1-button pressed to send to PCMH (cardiology or CT surgery)
- Study transferred w/in 30 min.
- Typical study 200-250 MB
- Study reviewed w/in 3 hr.
- Patient @ PCMH for procedure same or next day

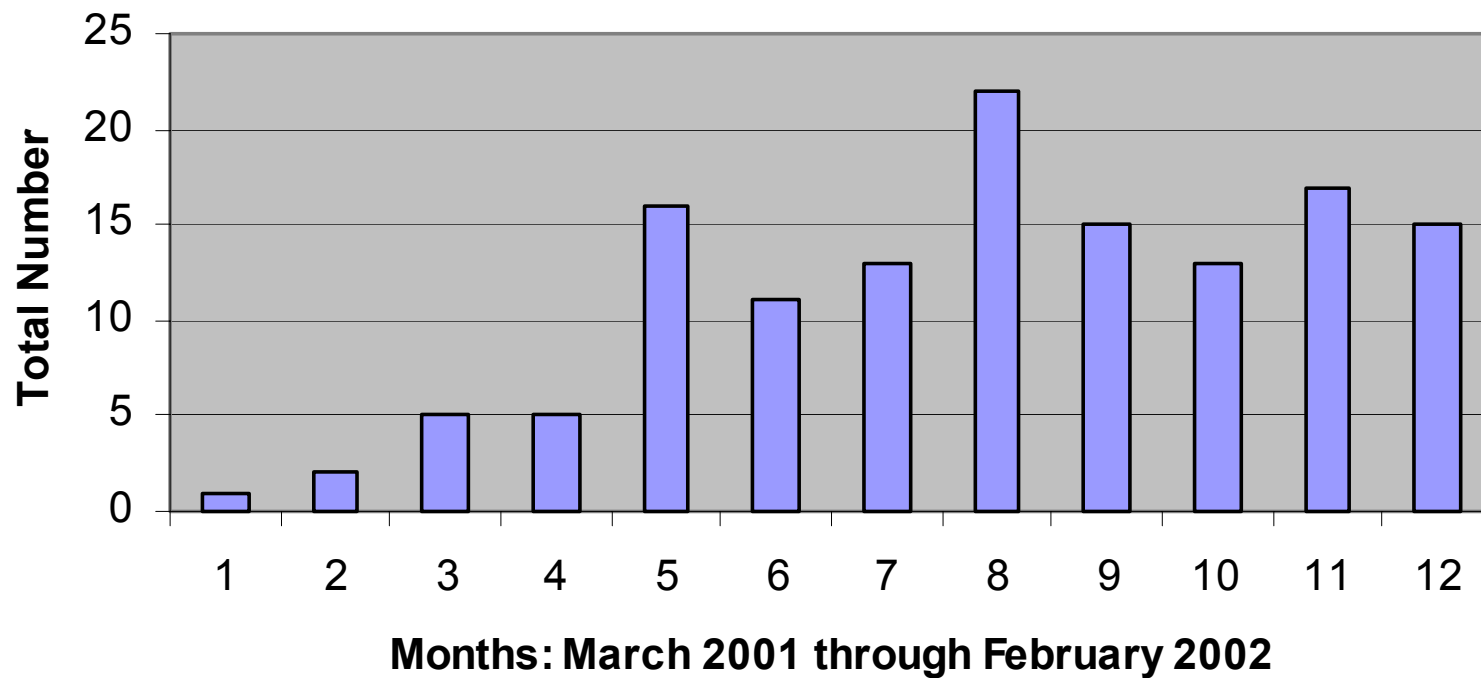
Technical Solution

- Linux PC's set up as DICOM workstations
- VPN over T-1 connection between facilities (SSH)
- 32-bit checksum & 1024-bit encryption
- Generated page to PCMH cardiology when study arrived

Cineangiograms

Number of Transmissions per Month

(Nash Hospital to Pitt Memorial Hospital)



Outcomes

- Reduced time-to-procedure
- Reduced hospital LOS, but not statistically significant ($p=0.09$)
- Increased # consults (and procedures)
- Started to use as 2nd opinion tool
- Hospital purchased COTS DICOM solution as a result – will expand to other cath labs in region













Major Technology Evaluations: *Distributed Multimedia Education*

Multimedia Pediatric Auscultation

- System developed for improving auscultation skills
- High-fidelity audio and video elements delivered over NGI
- Tested with 32 UNC-CH nursing students (via NCREN (I2))
 - Least experienced had most improvement
 - Correlation between time used and accuracy
 - Users rated system good to excellent
- 2 servers used (one for echo video)

Home

Choose a heart sound you wish to listen to

- | | |
|---|---|
|  Normal |  Pulmonic Stenosis |
|  Atrial Septal Defect |  Mitral Valve Regurgitation |
|  Ventricular Septal Defect |  Patent Ductus Arteriosus |
|  Functional Murmur |  Tetralogy of Fallot |
|  Aortic Stenosis |  Waveform Comparison |

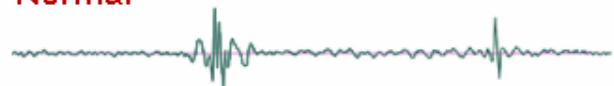
- | | |
|--|--|
|  Introduction |  About This Program |
|  Quiz Yourself Randomly |  Sound Advice |
|  Overview of Auscultation | |



Waveform Comparison

Move your mouse over the waveform you wish to listen to

Normal



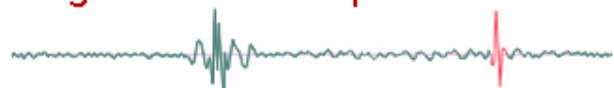
Atrial Septal Defect



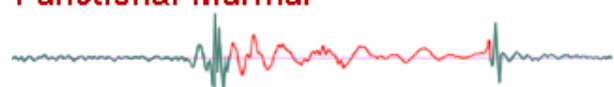
Small Ventricular Septal Defect



Large Ventricular Septal Defect



Functional Murmur



Aortic Stenosis



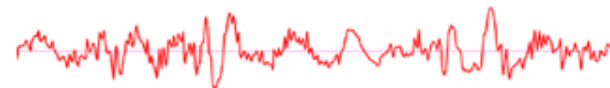
Pulmonic Stenosis



Tetralogy of Fallot



Patent Ductus Arteriosus



Mitral Valve Regurgitation



You are listening at the Upper left sternal border

Back



Home



Exit

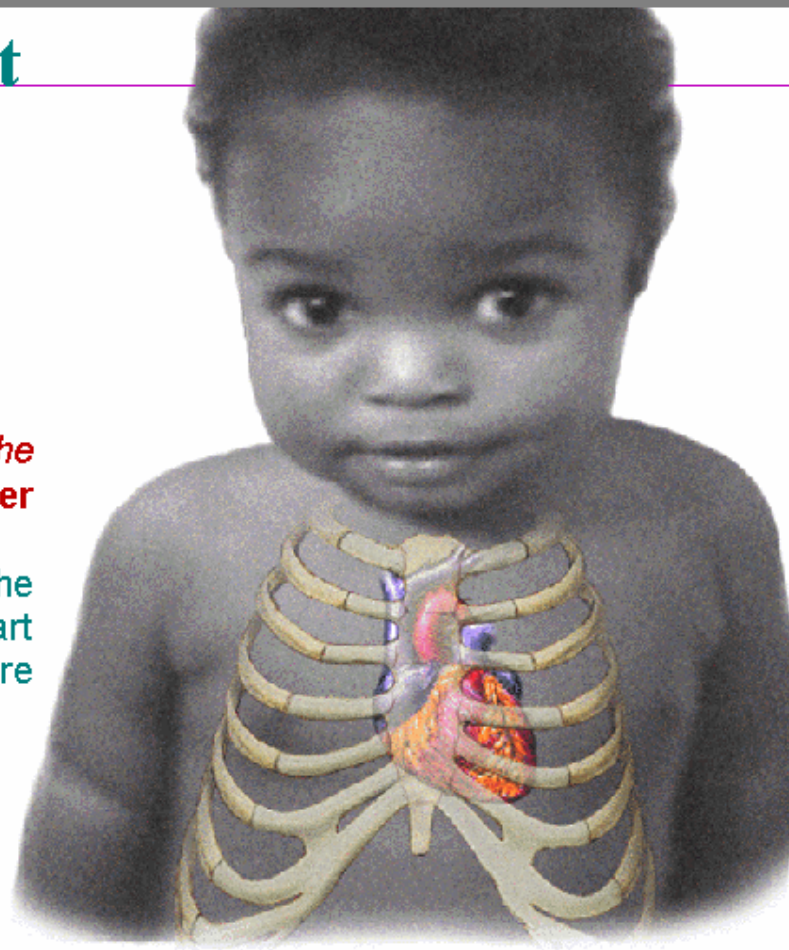


Atrial Septal Defect

*Move the mouse to
the area of the heart
you wish to listen to*

*You are listening at the
Upper left sternal border*

The systolic murmur and the
widely split second heart
sound are best heard here



About atrial septal
defect sounds



View echo

Back



Home

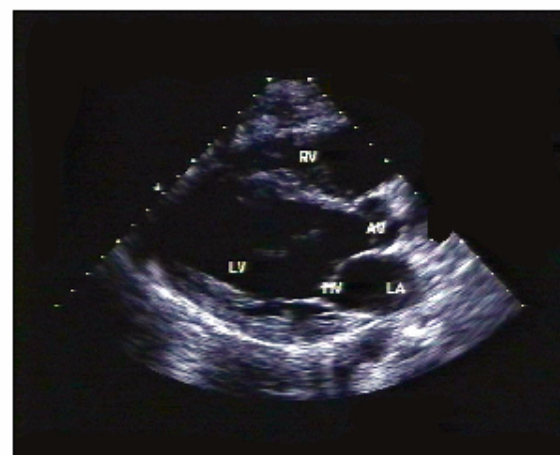


Exit



ASD Echocardiogram

Normal speed
Parasternal long axis view



Normal speed



Slow speed

Back



Home



Exit



Link

www.telemed.med.ecu.edu/HeartSounds/EchoHart3_TB86.tbk

Need to load Neuron 8.6 plug-in:

home.click2learn.com/en/toolbook/neuron.asp



Major Technology Evaluations: *Micro-webservers*

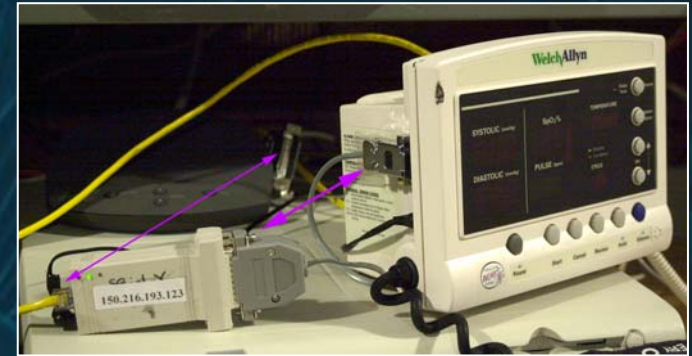
Micro-webservers

- Needed means for IP comms c/ biomedical devices
- Assessed 8 COTS micro-webservers
- Selected Picoserver
- Developed code for:
 - Welch Allyn VSM
 - Critikon Pro 400 VSM
 - Roche Accu-Chek glucometer



Micro-webservers

- Displayed in browser (IE)
- Cold Fusion as back end with VFP d/b
- Testing determined:
 - Max. 12 simultaneous requests
 - Command reliability: 92.5% load over T-1, 30% load over 10 Mb Ethernet
 - 60% fatal failures

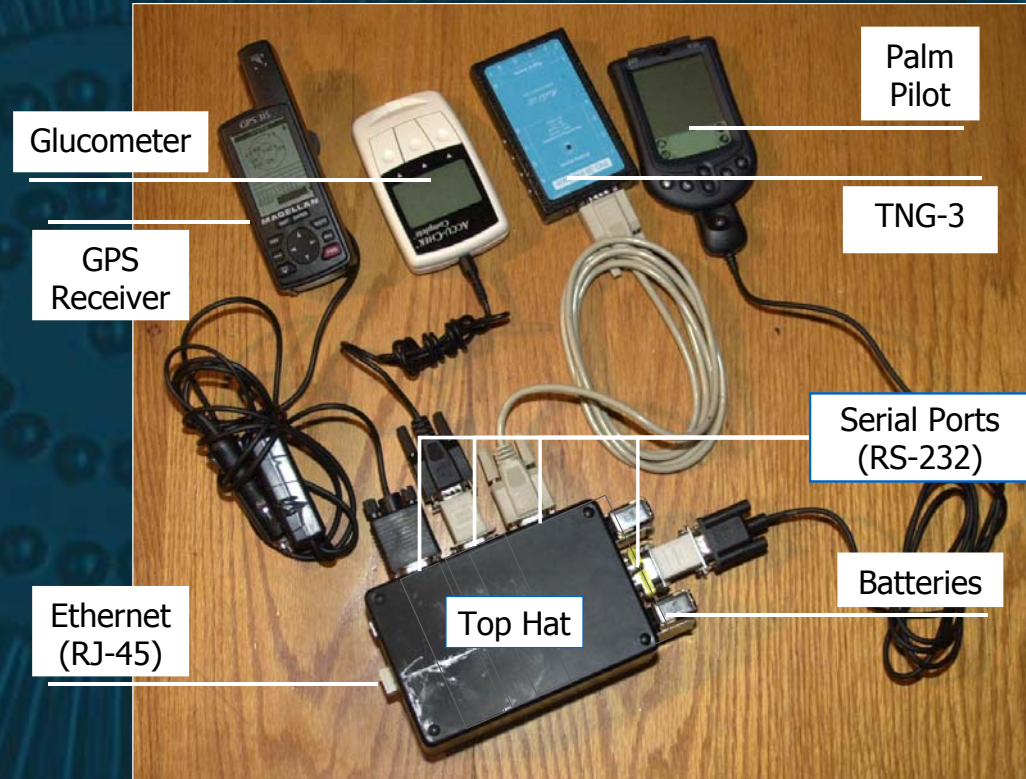


Accuracy (unloaded N/W)

	NGI			T1			DSL		
	WA n=104	Cr n=102	Accu n=103	WA n=106	Cr n=104	Accu n=105	WA n=120	Cr n=126	Accu n=103
Blood Pressure	7 (90.65)	0 (100)		6 (94.43)	1 (99.04)		7 (94.17)	15 (88.1)	
Pulse	2 (98.01)	0 (100)		8 (92.45)	2 (98.08)		5 (95.83)	10 (92.06)	
spO ₂	1 (99.04)	1 (99.02)		4 (96.23)	2 (98.08)		8 (93.33)	3 (97.62)	
Temp	2 (98.01)			6 (94.43)			10 (91.67)		
Glucose			3 (97.09)			5 (95.24)			5 (95.15)

TopHat

- 4 RS-232 i/f's
- AC, battery, or solar power
- Bluetooth (via serial adapter)
- Drivers ported for multiple devices
 - Biomedical
 - Environmental
 - GPS
 - PDA



Tele-Hearing System

- Audiometer retrofitted with microcontroller & microwebserver
- Audiologist remotely operates audiometer (Hz, dB) over IP N/W
- Responses logged in client S/W (PC or PDA)





Findings & Recommendations

Findings

- IP videoconferencing works, if you control the network
- IP video is sensitive (routers, NAT, firewalls, etc.)
 - Polycom recommends <1-2% packet loss
 - Seemingly minor factors can have major effects on performance, e.g. media converters
- Duplexing matters
 - Should hard code port settings
 - Half duplex worked best for μ -wave
- VLAN's work (when set correctly)

Findings (continued)

- Difficult to determine the best quantitative metric for IP video quality
- Temporal aspects of audio/video errors are the most significant.
 - Distribution of audio/video errors was a better indicator of videoconference quality than mean error rates
 - Short-lived, high-error periods more acceptable than chronic low-error conditions.
- Video quality threshold @ continuous loss of 6-7 video packets/min.

Findings (continued)

- New skill set required for tech. support
 - Traditionally telemedicine tech's have A/V production or telecommunications background
 - IP systems require knowledge of network eng. & operations, but a/v production elements still crucial
 - Future telemedicine technical support and operations teams will need both skill sets
 - Cross-training in both domains will be required.

Findings (continued)

- H.323 manages lost audio by repeating – this can sound like cardiac anomaly
- Similarly, crackles (lung sound) can be lost
- MPEG-2 best for *resolution*; video and audio (heart & lung sounds)
- Challenging to do N/W research when using production N/W elements. Several orgs. were involved:
 - University IT
 - Hospital IT (3 hospitals)
 - Our department (NLM research team & V/C ops)

Recommendations

- Set up PC's for monitoring and control
 - Use codecs' web interfaces
 - IP-enabled audiovisual routing
- Use switches instead of routers whenever possible
- Reset codecs frequently
 - Procedures should include rebooting codecs between consults, or at least between sessions of contiguous use.
- Build application-specific performance specifications into acceptance criteria

How to Address IP Challenges

- Overprovision your network
- Implement QOS mechanism
 - Works within your network/campus
 - In lab, we loaded N/W 100%, and could still get error-free video
- Avoid/eliminate bottlenecks
 - Hubs
 - Routers (use non-blocking wire-speed switches instead)
 - Firewalls
 - 802.11



The Future of IP Telemedicine

New A/V Standards

- H.264 video compression
 - Just ratified by ITU
 - Part of H.323
- MPEG-4
 - Recently adopted
 - Optimized for Internet/WWW multimedia
 - Scalable to support multiple bandwidths
 - Separate objects in stream (video, VRML, etc.)

Native IP Biomedical Telemetry

- Implemented intermediate solutions
 - μ -webserver
 - VGA out from EMG
- Ideally would have direct IP interface for biomedical devices
- Issues
 - Addressing (IPv6?)
 - Directory services/device descriptions
 - Security

Just-in-time telemedicine

- A combination of:
 - Real-time (synchronous) – what we do now
 - Videoconferencing
 - Data streaming/telemetry
 - Store and forward (asynchronous)
 - E-mail with file attachments
 - Consultation server
- Use minimum interactivity to facilitate interaction and higher-resolution photo's, video clips, data files as store-and-forward